

Ecologically Sustainable Design of Outdoor Spaces: Theory and Practice

Lina K. Kadhum^{1*}, Ashwaq Fadhel Alomare²
& Tahrir Taki Ali Almusawi³

¹Assistant Lecturer, ²Assistant Professor, ³Lecturer
Department of architecture, College of Engineering
Mustansiriyah University,
Iraq

Email: *linakifah33a@uomustansiriyah.edu.iq

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Abstract

The methods of dealing with and designing outdoor spaces differ according to different times, environmental conditions and societies. The pursuit of pleasure and joy from behind these designs achieve sustainable ecological values in design with care for the ecological environment. Given the local reality experienced in outdoor spaces and the pursuit of balance with Nature, the designers of outdoor spaces must recognize the role of these values and their impact on the awareness of society to take care of the ecological environment of the outdoor spaces.

This research examines outdoor spaces. It reviews the most important principles for sustainable design of them. The study emphasizes the importance of ecological aspects of outdoor spaces and the need to take care of the ecological environment. It addresses the issue of the absence of holistic studies that demonstrate sustainable ecological design of outdoor spaces. Thus, the aim of the research is to present the concepts of sustainable ecological design and to highlight the most important aspects and components associated with them. The intention is to facilitate the development of outdoor spaces.

The research produces a theoretical framework based on previous studies and propositions. It establishes the relationship of outdoor spaces with the ecological components through an analysis of global projects, providing suggestions on how to achieve ecological beauty

It employed case studies as a research methodology. Data was gathered by field studies. Descriptive and analytical research is also used. Comparative between selected international projects were conducted, to develop indicators.

The paper concludes that there is a lack of knowledge in applying these indicators in an environmental and sustainable manner to outdoor spaces

Keywords: Sustainable Design, Ecological Design, Ecosystem, Sustainable Outdoor Spaces, Ecological Outdoor Spaces.

Introduction

Urban outdoor spaces are the natural outlets of a city. There is thus a need to support the natural environment and to pay attention to the environment of the outdoor spaces. There is also a need for the protection of plants and animal diversity. Recently, the importance in achieving a balance between the natural environment and the built has come to light. In addition to the fact that a balance must be established between design, the ecological systems, and the social life in the designs of the outdoor spaces, they are considered basic planning elements that fulfill the psychological and physical human needs. On the one hand, outdoor spaces provide a set of functional, aesthetic, and ecological elements and on the other hand, their effect on the city lies in their preservation of the vitality of the ecosystem and the recipient's awareness of the tangible aesthetic values of the properties and characteristics of the outdoor spaces within the city. The huge diversity of natural forms teaches us that there are many ways, models, and systems to simulate Nature and take advantage of the energy present in a site and the model itself. Use of architecture is not only to organize space and social interactions but to create a balance with green spaces, the natural environment and the manufactured environment.

The Research Problem

This paper is based on the premise that there is no clear criteria for applying environmental determinants according to sustainable ecological design and its integration with the design elements of urban outdoor spaces. In this context, this research examines the role of sustainable ecological design and analyzes the impact of these standards on the environment and communities.

Its objectives are:

1. To evaluate the successful experiences in integrating the design of outdoor spaces with environmental determinants and comparing them with each other.
2. To offer legislators and decision makers principles to adopt sustainable environmental policies that support environmental design.

Theoretical Framework

Urban outdoor spaces are integral components of our urban and natural environments, providing essential areas for recreation, relaxation, and community engagement. However, the growing challenges of urbanization, habitat loss and climate change emphasize the need to prioritize ecological aspects within these spaces. This literature review explores existing research and scholarship related to the importance of ecological considerations in outdoor spaces and the imperative for sustainable ecological design. There is an imperative to prioritize the preservation of the natural environment and to give due consideration to the ecological aspects of outdoor spaces. Protecting plant and animal diversity is equally crucial. Recently, the significance of achieving a harmonious balance between the natural environment and urban development has gained prominence (Bolund & Hunhammer, 1999).

Furthermore, it is essential to establish an equilibrium among the design principles, ecological systems, and the social aspects within outdoor space planning. These elements serve as foundational components that cater to both the psychological and physical needs of people. Outdoor spaces serve a dual role, offering functional, aesthetic, and ecological elements, while also contributing to the city's vitality by preserving ecosystems and enhancing residents' awareness of the tangible aesthetic qualities inherent in urban outdoor spaces (Svendsen et al. 2016).

Sustainable Ecological Design

Sustainable ecological design is an interdisciplinary field that aims to create harmonious environments by integrating ecological principles into the planning and development of outdoor spaces (Holling, 1973).

It is achieved by consuming less energy and providing the highest quality of natural and artificial lighting, conserving materials and natural resources, improving the quality of the

internal environment and protecting internal and external water sources. It is a design style that bases its principles on natural design. It is not a new style in architecture like modernity, but a style of design thinking based on ecological principles, in contrast to the current style of design that neglects the region, the environment and energy consumption (Hsin, 1996).

There is no doubt that Nature is efficient and effective, as it produces without waste. The new sustainable ecological design processes require that each product or process be responsible and reviewed from the perspective of 'new' and include the environmental and human health impacts on which decisions must be based (Mendler, 2000).

It can be said that sustainable design includes environmentally friendly and human values in the design of outdoor spaces with the best materials that do not harm the environment. Its operation must produce the highest possible efficiency and the longest lifespan, as well as the flexible ability to be developed as needed (Holling, 1973)

Ecological Design of Urban Outdoor Spaces

Outdoor spaces play a vital role in providing ecosystem services to urban areas. Bolund and Hunhammar (1999) highlight the importance of these services, including air purification and stormwater management. Green infrastructure features like green roofs (Getter & Rowe, 2006) contribute significantly to these services.

McHarg described the ecological design of urban outdoor spaces as understanding outdoor space within the context of the surrounding ecosystem, and not only a group of abiotic components, but rather it is seen as a group of living components that work in an integrated manner (McHarg, 1969)

In ecological approaches to urban outdoor space, the environment must take into account the physical (inorganic) and the biological (organic) biosphere. However, it is noticeable that in many projects, the designers often neglect them due to the ecological considerations of the project sites (McHarg, 1969).

Therefore, urban and architectural movements and trends designed for outdoor spaces today must work by going beyond traditional methods towards designing a complex, organized and strategic ecological landscape that supports participation. The approaches developed by ecological planning, aimed at providing a scenario for decision-making in the development process of a given area, should contain many different considerations (Avila, 2011).

The eco-design approach, influenced by organic physics, societal culture, and information, guides decision-making for urban outdoor spaces. McHarg's "Design with Nature" (1967) introduced the concept of ecological design, emphasizing the interdependence of social, biophysical, and holistic factors in outdoor space utilization. Avila (2011) adds four eco-design approaches: expert, materialistic, perceptual, and existential, which help understand human interactions with ecological outdoor spaces. These approaches consider factors like aesthetics, hierarchy of components, ecological boundaries, social diversity, visual balance, repetitive rhythm, contrast, and the geometric system. In essence, ecological design analyzes ecosystem functions and their impact on outdoor space design decisions, encompassing biological, physical and socio-cultural aspects (Avila 2011).

It can thus be concluded that the ecology of outdoor spaces represents the analysis of the functions of the ecosystem and its impact on the decision-making process in the design of outdoor spaces and its relationship to its biological (organic) and physical (inorganic) surroundings and social-cultural values.

Ecosystem

An accurate understanding of the idea of the ecosystem shows that this system is biological before it relates any design to its environment. This means that the ecosystem of a site of any project must be analyzed holistically to understand its components, operations, and susceptibility to change design interventions (McHarg, 1969). The function of the ecosystem is socially understood by defining and measuring ecological indicators such as plant diversity, flexibility in dealing with the biological environment, and sustainability and not only knowing

how to measure it, but also knowing its degrees, levels, and complex groups of form in ecological behavior in ecological outdoor spaces (Klein, 2013).

The functional relationship between society and its environment is characterized by the ecological unity within Nature.

- The system formed as a result of the interaction between a community of living organisms and the natural environment.
 - A community of living and non-living things working together.
 - The community plus the natural environment that occupies a specific time can exist on any scale from the size of the small pool of the environment, the diversity of the current variety, and the interactions between the species and the environment.
- Therefore, the functional complexity of an ecosystem can anticipate the increase in number, diversification, and taxonomy of the current species, and the vertical and horizontal complexity of the natural environment (Harrison, 2004).

Ecological Beauty

The concept of ecological beauty in outdoor spaces emerged in the latter part of the 20th century as a modern aesthetic philosophy. It serves as a reaction to growing environmental concerns in European outdoor areas (Suprabha, 2010).

Gabester et al. (2007) define ecological beauty in outdoor spaces as the human desire to derive pleasure from spaces that offer ecological benefits, and beautiful outdoor spaces evoke pleasure through their environmental features. Enhancing ecological beauty can influence community behavior toward ecosystem care (Klein, 2013). Human appreciation of beauty in outdoor spaces is driven by qualities that stimulate knowledge, including elements within these spaces, perceptions of space, and movement among these elements.

Information processing theory identifies four characteristics of ecologically beautiful outdoor spaces: unity, accessibility, complexity, and ambiguity (Baker, 2009). Three approaches to achieving ecological beauty in outdoor spaces are outlined by Laurie (1989). They are: ecological landscape orientation, functional orientation, and people's pleasure orientation. These approaches encompass connecting with Nature, integrating objective elements, recycling, rehabilitation, maintenance, defining identity, and fulfilling needs related to beauty (Laurie, 1989). Fry et al. (2009) propose communication between visual aesthetics and ecological indicators in outdoor spaces. This involves analyzing outdoor spaces based on these indicators and integrating aesthetic and ecological elements. Key dimensions include place maintenance, harmony, the scale of place, simplicity, historical significance, and the seasonal variability of the natural environment (Fry et al., 2009).

In summary, ecological beauty in outdoor spaces integrates pleasure with the imperative to preserve ecosystems. It encompasses a range of aesthetic, ecological, and cultural dimensions, influencing human behavior and design decisions to promote harmony between natural and designed elements (Suprabha, 2010; Gabester et al., 2007; Baker, 2009; Laurie, 1989; Fry et al., 2009).

Aesthetic appearance of ecological outdoor spaces stems from their historical associations, cultural resources, and meanings drawn from them. Ecological beauty focuses on the protection of ecological processes that operate outside the human perception of place and scale. The human aesthetic experience is also part of the ecological beauty standard. It's also part of an efficient ecosystem. For this to be accepted socially, the external spaces must be concerned with the ecological aesthetic relationship and the unity relationship between form and function (Klein, 2013). Human aesthetic experience is influenced by satisfaction and awareness of biological needs (eating, drinking, shelter, and safety) and human preferences for parks begin with the sight of green expanses of grass, the presence of tree shapes, and scenes containing water. Indeed, these preferences are linked to evidence of human survival potential. Klein (2013) indicates that the criteria for achieving ecological beauty are related to the following:

- Similar scenes of green rural expanses and wild outdoor shapes.
- Providing distinct function elements or unfamiliar elements.

- Providing access roads, appropriate viewing angles, and paths for bicycles and pedestrians.
- Stimulating the cultivation of outdoor spaces that are linked to physical beauty with care and the possibility of continuity and survival.
- Providing cultural external spaces and a sense of belonging and identity.
- Providing diversity in achieving the aesthetic experience.

Klein (2013) says that polite, clean, and organized green spaces are a sign of health and goodness, taking into account a sense of comfort and a sense of place and their role in increasing societal interest in aesthetic values: ecological. The assimilation of the ecological outdoor space is linked to the cultural values intertwined with the visual scene in different dimensions, coinciding with conflicting feelings that perceive the aesthetic experience: visual, auditory, olfactory, or tactile, or they may be combined within the outdoor spaces. Through the repetition of formations and spatial relationships in the outdoor spaces, a set of visual formations can be available that enhances clarity and coherence. Aesthetic values are achieved through a selected base of local and national species of plants and living organisms and their composition for different and diverse assemblies in the outdoor spaces. They are also achieved by integrating a group of factors that make up the outdoor spaces that create a system which attracts and entertains the inhabitants and contains visual and physical interpretations to interact with it. (Klein, 2013)

Designing A Sustainable Urban Outdoor Space

The desire to have a healthy, enjoyable and beautiful outdoor space that is less polluted and harmful to the environment was the first goal of designing a sustainable outdoor space. Thus, people have started talking about gardens, less toxic and polluted outdoor spaces, and less harmful ways to maintain them. Sustainable outdoor spaces are not only important for the environment and climate, but are related to other aspects of them such as the social aspect. Thus, it is concerned with improving the quality of life through healthy and correct practices in these spaces. The aesthetic aspect is concerned with the environment in which people live and make it livable: produce a living environment. The environmental aspect deals with the concern for the climatic environment and the improvement of climate conditions in the local environment, leading to sustainability. Outdoor space is thus a way to strengthen our connection with our environment, which in turn supports us (Aeck, 2008).

Designing Sustainable Outdoor Spaces

According to Dober (2000), the following principles stand.

- Designing with the nature of the site, maintaining its health and minimizing damage as much as possible, such as the need to cut down certain trees (Dober, 2000).
- Using the plants appropriately (planting the right plant in the right place) that suits the conditions (temperature, humidity, soil, and water). This is what is meant by encouraging the cultivation of local plants, which reduces the effort to make plants fit the environment in which they are grown. If it is alien, it may constitute an additional burden on the environment
- Avoiding the use of materials that require constant replacement (such as structures used for irrigation, and space maintenance equipment) to reduce losses.
- Using the outdoor spaces to conserve energy and prevent pollution through proper afforestation by choosing the right shapes and the correct locations for the plants. This means to provide shade in the summer, and allow sunlight in the winter, reduce air pollution, and noise as every hundred trees work to get rid or reduce one ton of CO₂, and half a ton of the rest of the polluted gases every year. The same number works to mitigate atmosphere, and provide the state of adaptation at a rate of 3 trees for each house, i.e., providing adaptation for 33 houses.
- Cultivating for a longer life using healthy plants beneficial to the environment.

- Adopting rainwater conservation techniques and making use of them, such as making special storage basins, and linking them to the space watering network.
- Using an efficient irrigation system that ensures water conservation and maximum utilization.
- Choosing the correct covering materials, and avoiding covering large areas of outdoor spaces with materials that do not allow water permeation because the use of types of concrete with spongy specifications (Porous) helps the passage of water into the soil. Using bricks as water permeates from the joints of the bricklayer if it is used on the soil to make corridors. Encouraging the use of reused and recycled materials within the spaces, and reducing dependence on raw materials.
- Using climbing plants to make fences to form sustainable green furnishing, and a pleasant view. Adopting stones and also wood as natural materials.

Maintaining Sustainable Urban Outdoor Spaces

According to Williams (2007), they involve the following.

- Continuous and regular monitoring and evaluation of the outdoor spaces.
- Increased education in terms of sustainability and control of outdoor spaces.
- Reducing the use of chemicals that are harmful.
- Adopting natural fertilization practices such as the use of organic analysis boxes in space.
- Reducing the dependence of potable water in irrigation works and trying to use rainwater and treated water.
- Using manual equipment while adopting devices and equipment that depend on electricity as more fuel than kerosene (Williams, 2007)

From the foregoing, it is concluded that the design and maintenance of outdoor spaces in this manner will produce sustainable outdoor spaces, thereby achieving a set of important benefits for space users and the surrounding environment.

Ecology of Outdoor Spaces

Designing ecological outdoor spaces as a system had begun with two evolutionary lines: the first is the European School and the second is the American School. The European school has a long history close to the beginning of ecological ideas and emphasizes modularity and classification, but its main focus is on the built system.

The American school is relatively new. It appeared in the early eighties, as it was started for a specific reason by a workshop in Ellerton Park when a meeting was held in which it was recognized that the ecological outdoor spaces are concerned with the cultural field. They worked in contrast with the European school, where more emphasis is placed on the natural system and a semi-natural system (McGarigal, 2001).

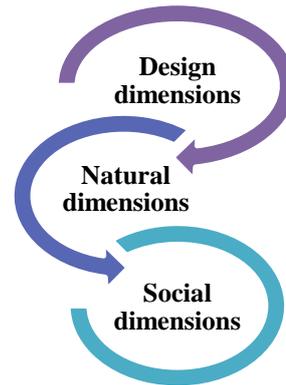
According to Williams (2007), the benefits of sustainable outdoor spaces are as follows.

- Reducing pollution, losses of resources, and reducing environmental impact.
- Improving wildlife and preserving biological diversity.
- A healthy and healthy environment.
- Preserving water wealth through sustainable water conservation practices.
- Reducing rainwater losses in rainy areas by making use of it.
- Providing the opportunity to enjoy nature properly and scientifically by applying the principles of sustainability.
- Reducing the effort to maintain the space.
- Achieving environmental comfort and economic savings by reducing the energy needed by the building for cooling and heating loads by (30-50%).
- Reduce noise.
- 10 - Conservation of the potential energy in the natural environment.

Vocabulary of The Theoretical Framework

Through what was extracted from the studies unearthed by research as presented above, the indicators of achieving sustainable ecological design in outdoor spaces has been produced. They are associated with three main dimensions:

1. Natural dimensions,
2. Design dimensions,
3. Social dimensions



They can be graphically presented as shown in the Table 01.

Table 1: key principles of sustainability evident in the open space in outdoor spaces
Source: Authors

Main indicators	Secondary indicators	Possible variants		
Natural dimensions	Simulating Nature	Make Nature clear		
		Nature's use of ecological determinants		
		Natural models of shaping	Water ponds - flowing water Herbs - trees	
Design dimensions	Harmony	Accessibility	Provide function elements and symbols	
			Determining the dimensions of the external spaces	
			Providing access and movement for bicycles and pedestrians	
	Complexity	Color contrast	The size	The size
			Texture	Texture
		Plant diversity	Plant diversity	
	Mystery	Diversity in the visual landscape	Watery	Watery
			Furniture	Furniture
	Sustainability	Engineering system	Organic (biological) formations	
			Inorganic (physical) formations	
Technology		Animated shaders		
		Energy-saving equipment		
Materials		Choosing sponge concrete materials and breaking bricks allows water to penetrate the soil	Choosing sponge concrete materials and breaking bricks allows water to penetrate the soil	
		Use of non-raw materials	Use of non-raw materials	
Site maintenance	Avoid changing fixtures and equipment			
Social dimensions Main indicators	Sense of place Identity	Confirmation of the identity and icon of the place		
		Belonging through the interplay of place elements		

The Research Hypothesis

This research is based on a hypothesis as follows.

1. Implementing ecologically sustainable design principles in outdoor spaces will lead to a positive impact on the environment, enhance the quality of life for users, and promote long term ecological health and diversity. This hypothesis suggests that the application of sustainable design concepts in outdoor spaces will result in specific positive outcomes related to environmental preservation, user experience, and ecological well-being. The research aims to test and provide evidence to support or refute this hypothesis through investigation and analysis.

Research Methodology

This research adopted a case study method to achieve the objectives of the research. It involves two parts,

1. A descriptive analysis of the key principles of sustainability evident in the open spaces
2. Measuring the indicators of sustainable ecological design in the outdoor spaces

This is aimed at processing the data. The two international projects selected are as follows: The Roof Garden Project (Academia de Ciencias de California) and Little Island Sustainable Design (La pequeña isla de Heatherwick Studio).

These projects were studied as real-life, practical, and contemporary examples, measuring verification values for each of the detailed indicators (main indicators: natural dimension, design dimension and social dimension) and (secondary indicator: simulating Nature, Harmony, Engineering systems and sustainability)

The paper thus starts with a general description of the two samples selected for the practical study for examining key principles such as Biodiversity, Energy efficiency, Community engagement, Aesthetics etc.

The Case Study (A)

The Roof Garden project

(Academia de Ciencias de California / Renzo Piano Building Workshop + Stantec Architecture)

The project's rooftop garden in California is a beautiful embodiment of ecological design within an urban context. Encompassing a vast expanse of approximately 82,881 square meters, this verdant oasis seamlessly blends with the urban landscape creating a harmonious architectural feature that appears as an extension of the natural environment. Circular openings resembling skylights allow ample natural light to permeate the garden, enhancing its aesthetic allure and ensuring the vitality of the greenery. This rooftop garden epitomizes the project's dedication to ecological design principles and its mission to explore, elucidate, and safeguard the natural world and its ecosystems within an urban context. This green oasis is located atop a workshop building, and its design embodies several key principles of sustainability:

Biodiversity:

The rooftop garden features a diverse range of plant species carefully selected for their resilience and ability to thrive in an urban environment. This biodiversity promotes local ecosystems, supports pollinators, and contributes to urban wildlife habitat.

Stormwater Management:

One of the standout features of this sustainable design is its advanced stormwater management system. The green roof effectively absorbs and retains 91-92% of the rainwater, reducing runoff and helping to mitigate the urban heat island effect. Rainwater is channeled for irrigation, reducing the need for potable water.

Energy Efficiency:

Renzo Piano's design incorporates energy-efficient elements, such as strategically placed trees and vegetation that provide natural shading to the workshop below. This reduces the building's cooling needs during hot weather, contributing to energy conservation. Also incorporates photovoltaic cells, harnessing the power of the sun to generate 1 KW of electricity, covering 81% of the building's energy needs.

Insulation: The thick vegetation layer on the rooftop acts as natural insulation, regulating temperatures within the workshop. This decreases the demand for heating in the winter and cooling in the summer, leading to energy savings.

Aesthetic Appeal: Beyond its environmental benefits, the rooftop garden enhances the aesthetic quality of the workshop design. It offers a serene and natural environment for workers and visitors, creating a pleasant and harmonious workspace.

Community Engagement: This sustainable design isn't just about the environment; it's also about community engagement. The rooftop garden may serve as a gathering space, an outdoor classroom, or a place for relaxation, fostering a sense of community and well-being among workshop occupants.

Long term Viability: Renzo Piano's design prioritizes the long-term viability of the rooftop garden. Maintenance plans and sustainable practices, such as composting and organic pest control, ensure that the garden remains healthy and vibrant over time.



Fig. 1: The roof Garden project

Source: Archdaily.com

The Case Study (B)

Little Island sustainable design (La pequeña isla de Heatherwick Studio crea un paisaje artificial sobre el río Hudson)

Little Island's open space design in New York over the Hudson River exemplifies sustainability through its commitment to biodiversity, environmental harmony, structural integration, accessibility, educational and community spaces, alternative event venues, and urban integration. It showcases how thoughtful design can enhance both the ecological and social sustainability of urban environments. Below are the key principles of sustainability evident in this open space include:

Biodiversity: The project prioritizes biodiversity through the use of a variety of trees, shrubs, herbs, and perennials, creating a diverse and harmonious landscape that enhances ecological richness.

Environmental Harmony: The design seamlessly blends with the natural environment, creating a space that harmonizes with the surrounding landscapes. The choice of materials and their textures, whether soft or rough, connects with nature, fostering a sense of environmental harmony.

Structural Integration: The use of structural columns, such as the 132 tulip-shaped concrete piles, not only serves as a key design element but also contributes to the structural resilience of the project. These columns transform into lush plantations, enhancing the aesthetic appeal while contributing to sustainability.

Accessibility and Movement: The design incorporates movement corridors and paths that ensure easy access for visitors, promoting an inclusive and welcoming environment for all. These paths also allow for various viewpoints, enriching the visitor experience.

Educational and Community Spaces: Little Island incorporates educational and community open spaces, promoting engagement and learning about the environment. This fosters a sense of community and encourages environmental awareness.

Alternative Venue: The project provides an alternative venue for public gatherings, presentations, and performances, reducing the need for energy-intensive indoor venues and contributing to the sustainability of public events.

Urban Integration: The design aligns with the New York Street network, enhancing urban connectivity and accessibility while maintaining a green and natural atmosphere.



Fig. 2: Little island sustainable design
Source: ArchDaily.com

By assessing the two case studies, the paper provides a table showing the extent to which their outdoor spaces have achieved ecological design.

Table 2: Key analysis to assess outdoor spaces that achieved ecological design for both case studies A and B (X available & 0 unavailable)
Source Author

Key Analysis	Case study A	Case study B
Biodiversity	X	X
Energy efficiency	X	X
Insulation	X	0
Aesthetic	X	0
Community engagement	X	X
Long term viability	X	0
Environment harmony	0	X
Structural integration	X	X
Accessibility & Movement	X	X
Education & Community spaces	0	X
Venue for public events	0	X

Urban Integration	X	X
Water management	X	X
Greenery	X	X

The second part of the methodology involves the measurement of several indicators. The selected projects are contemporary in design and have been implemented on the ground. They have a degree of diversification in simulating Nature or in terms of the design dimensions of sustainable engineering systems. They provide a clear scope for comparison between the characteristics and features and comes up with more objective and comprehensive results.

Table 3: Description and measurement form to measure the variables through the values (1-0), as they represent (0: an unrealized value), (1: a realized value) and the percentages of the total variables

Source: Authors

Main Indicators	secondary indicators	possible variants		Sample	SampleB	total	percentage	
natural dimensions	simulating nature	Make Nature clear		1	1	2	100 %	
		Nature's use of ecological determinants		1	1	2	100 %	
		Natural Models of Shaping	Water Ponds - Flowing Water	1	1	2	100 %	
			herbs - trees	1	1	2	100 %	
design dimensions	harmony	accessibility	Provide function elements and symbols	1	1	2	100 %	
			Determining the dimensions of the external spaces	1	1	2	100 %	
			Providing access and movement for bicycles and pedestrians	1	1	2	100 %	
		complexity	antonym	the color	1	1	2	100 %
				the size	1	1	2	100 %
				texture	1	1	2	100 %
			Diversity	vegan	1	1	2	100 %
				water	0	1	1	50%
				optical viewfinder	1	1	2	100 %
	mystery	Diversity in the visual landscape	1	0	1	50%		
	engineering system	organic (biological) formations		1	1	2	100 %	
		Inorganic (physical) formations		1	0	1	50%	
	Sustainability	technology	Animated shaders		1	0	1	50%
			energy saving equipment		1	0	1	50%
Materials		Material selection	Sponge concrete and breaking bricks allow water to		1	1	2	100 %

			penetrate the soil					
			material use	not raw	1	1	2	100 %
social dimensions Main Indicators	sense of place	site maintenance	Avoid changing fixtures and equipment		1	1	2	100 %
	identity	Confirm the identity of the place icon		1	1	2	100 %	
			Belonging through the interplay of place elements		1	1	2	100 %

Conclusions

In conclusion our analysis of the two projects, in comparison with the hypothesis, assesses the extent to which their outdoor spaces achieved ecological design based on the established evaluation criteria. Through a thorough examination of the two case studies, the paper has drawn several conclusions as follows.

Sustainable Water Management

Both projects have demonstrated a strong commitment to sustainable water management. The California rooftop garden efficiently absorbed and repurposed rainwater, conserving this precious resource. Similarly, the Little Island project, situated over the Hudson River, showcased a harmonious integration of water features within its landscape design, reflecting an eco-conscious approach.

Biodiversity and Greenery

Both projects have excelled in enhancing biodiversity through their extensive use of vegetation. The California rooftop garden featured lush plantings, while Little Island incorporated a diverse range of trees, shrubs, herbs, and perennials. These choices not only added to the aesthetic appeal but also contributed to the ecological richness of the spaces.

Structural Elements

Both projects have ingeniously integrated structural elements into their designs. The California rooftop garden's tulip-shaped concrete piles served as both design focal points and hosts for thriving plant life. In contrast, Little Island's structural columns transformed into stunning plantations, elevating the aesthetic while reinforcing the structural integrity of the project.

Accessibility and Community

Both projects have prioritized accessibility and community engagement. The California rooftop garden offered an alternative venue for gatherings and educational purposes, fostering a sense of community and environmental awareness. Similarly, Little Island incorporated spaces for presentations and performances, reducing the need for energy-intensive indoor venues while promoting community engagement.

Urban Integration

Both projects seamlessly integrated with their urban surroundings. The California rooftop garden's undulating design and circular skylights enhanced the aesthetic appeal and connected the green space with the cityscape. Little Island's alignment with the New York street network exemplified urban integration while maintaining a green and natural atmosphere.

Discussion

From examining the two case studies, it is clear that both projects have made significant steps in achieving ecological design based on the evaluation criteria. They have successfully demonstrated sustainable water management, promoted biodiversity and greenery, creatively

incorporated structural elements, prioritized accessibility and community engagement, and seamlessly integrated with their urban contexts.

These findings support the hypothesis that both outdoor spaces have achieved ecological design to a commendable extent. They serve as inspiring examples of how innovative design approaches can harmoniously merge human made structures with the natural environment, contributing to both ecological sustainability and the well-being of the communities they serve.

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